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INNOVATION: EXPLORING THE KNOWLEDGE BASE

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Abstract

New types of knowledge, and new ways of organising the production of it, may emerge as knowledge producers respond to the challenges posed by a changing society. This study will focus on the core knowledge of one such emerging field, namely, innovation studies, i.e. the attempt to understand the social process which enables the continuation of qualitative improvements of products, technologies, and the organisation of economic activities. To explore the knowledge base of innovation, a new data base of references in scholarly surveys of various aspects of innovation, mostly published in "handbooks", is developed. The paper describes the process that led to the construction of the data base and its exploitation in identifying the core literature on innovation. Furthermore, the characteristics of this literature, the central contributors and the use of the literature (as reflected by references to this core literature in scholarly journals) are analysed. Finally, cluster analysis is used to make inferences about how the field is structured and its links with different disciplinary and cross-disciplinary contexts.

Keywords: Innovation, cross-disciplinarity, emerging scientific field, social science

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1. Introduction

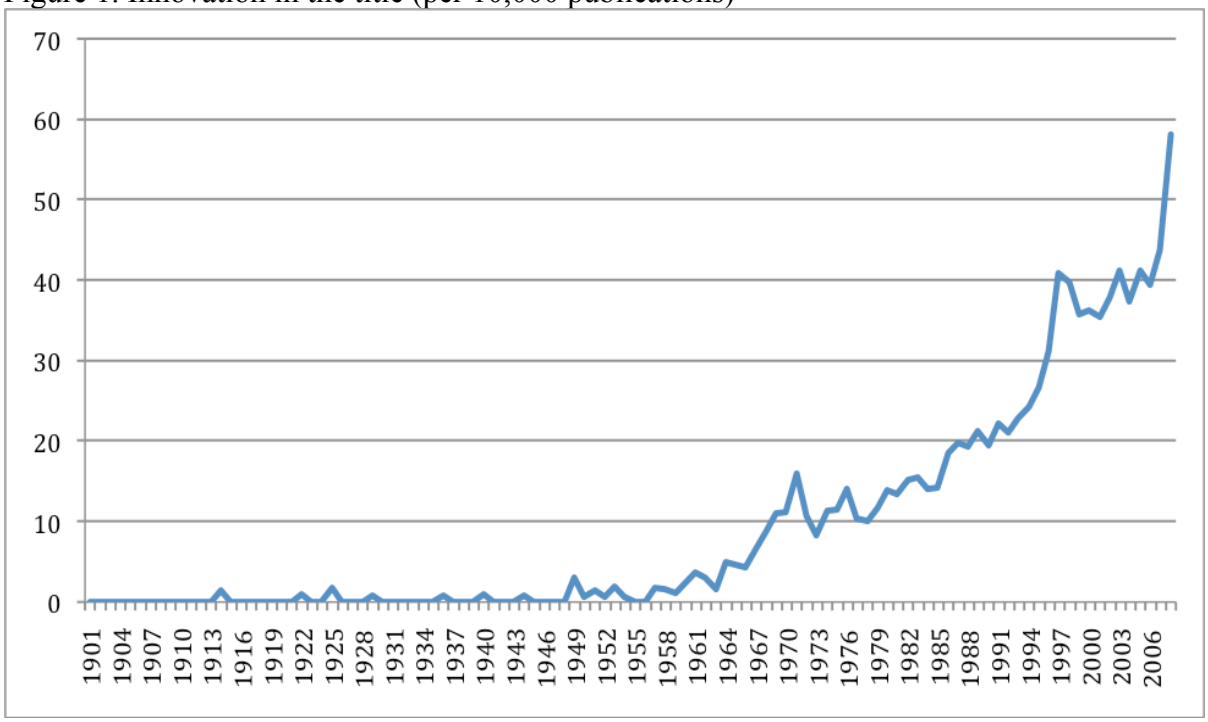
As the society develops and changes the need for knowledge may change too. New types of knowledge, and new ways of organising the production of it, may emerge as knowledge producers respond to the challenges posed by a changing society. In fact, the existing disciplines within the social sciences are themselves (relatively recent) examples of how new knowledge fields emerge and gradually establish themselves with appropriate organisations and institutions (Merton, 1973). There is no reason to believe that the existing pattern of organisation in the social sciences represents the end of history in this respect. On the contrary, new scientific fields are emerging all the time, within and across existing disciplines (Becher and Trowler, 2001; Whitley, 2000). This study will focus on one such emerging field, namely, innovation studies, i.e. the attempt to understand the social process which enables the continuation of qualitative improvements of products, technologies, and the organisation of economic activities. The study will explore the cognitive characteristics of the field, its links to other areas of science, as well as possible challenges/future prospects.

The field of innovation studies has grown tremendously in recent years, and probably several thousand academics worldwide are currently working on these issues (Fagerberg and Verspagen, 2009). However, although innovation is a very fashionable topic today, this has not always been the case. In fact, back in the early part of the previous century, at a time when the present social sciences were in an emergent state, very little attention was paid to the subject. Exceptions that prove the role include Gabriel Tarde (1903), a French judge who became interested in imitation and developed an original approach to the study of the subject, and Joseph Schumpeter (1911, 1942), who advanced a theory in which innovations, and the social agents underpinning them, were seen to be the driving forces of economic development. The topic received more attention around the time of the Second World War, when policy makers, first in the US and then elsewhere, became interested in R&D and innovation as an important impetus to progress in the military and (to a lesser extent) the civil sector (Godin, 2006; Hounshell, 2000). However, it was not until the 1960s, half a century after Schumpeter first presented his theory and a decade after his death, that there was a real surge of interest in the subject. During the course of a few years several important contributions emerged within different disciplines.[1] The first cross-disciplinary research

[1] This applies, for instance, to economics (Nelson, 1959; Schmookler, 1966), management (Burns and Stalker, 1961) and sociology (Rogers, 1962; Coleman et al., 1966).

centres on the topic were established in the mid 1960s, of which SPRU (Science and Technology Policy Research) at the University of Sussex came to be the most important.[2] Research in this area has flourished since the 1960s, with a particularly strong growth in the 1990s (Figure 1). Several specialised journals and professional societies of interest in this field have also emerged.[3]

Figure 1. Innovation in the title (per 10,000 publications)



Note: Publications in English language with a string innovat* in the title as a share of 10,000 of all annual additions to the British Library Integrated Catalogue 1901-2008

As in other areas of science, one important way in which social science renews itself is by responding to the emergence of new "problems", pointing to the scarcity or lack of relevance of the received knowledge. Such challenges, especially when accompanied by new resources, may attract researchers from a variety of backgrounds and lead to the creation of new research communities, with institutions and organisations designed to promote scientific progress in the area. Such institutional and organisational features may be of great help when exploring the cognitive characteristics of a field, because they make it easier to identify the most important contributions and contributors. For example, in their study of the field of Strategic

[2] SPRU was established in 1966. Later many others followed, with an increasingly explicit focus on innovation. Through a web-search, Fagerberg and Verspagen (2009) identified more than a hundred such research centres or departments worldwide within the social sciences, more than eighty percent of which were located in universities.

[3] The most important are the International Joseph Schumpeter Society, founded in 1986, and the Technology and Innovation Management Division (TIM) of the (American) Academy of Management, from 1987.

Management, Hambrick and Chen (2008) were able to identify the central contributions/contributors to that field because it was organised around a society and a journal (Strategic Management Society and Strategic Management Journal). However, the degree of institutionalisation and organisation may vary a great deal across different fields. Although, as mentioned, some professional meeting places have also emerged for Innovation Studies, there is no society which maps the entire field (Fagerberg and Verspagen, 2009). Furthermore, while the journal Research Policy is generally acknowledged to be an important publishing outlet for this type of work,[4] there is also a sprinkling of other publication channels which are made use of by researchers in this area. Thus, it may be necessary to look elsewhere for ways to identify the central scholarly contributions and, therefore, the cognitive characteristics of the field.[5]

A different way of studying the cognitive characteristics of a field, which may be more applicable to the present case, consists of identifying the core contributions by means of expert assessments (Crane, 1969, 1972). This approach exploits the fact that a number of authoritative contributions surveying the field or important parts of it already exist, often published in the form of so-called "handbooks". It seems reasonable to assume that the authors of such surveys include references to the most important scholarly contributions of relevance to their topics. Although the topics of these surveys will differ somewhat, as may the references, some contributions may be referred to many times simply because they are considered to be particularly central, i.e. they represent the core knowledge of the field. It will be assumed, therefore, that the subset of references which are referred to many times by different experts constitutes the core contribution in this area.

The structure of this paper is as follows. The next section provides a detailed description of the process which led to the identification of the core literature in this area. The characteristics of this literature are then analysed, both in terms of thematic priorities and the background

[4] In 1972, Christopher Freeman, the first director of SPRU, founded Research Policy, the first specialised journal focusing on R&D and innovation.

[5] This is also why Fagerberg and Verspagen (2009) felt compelled to collect their own data by means of a self-selecting "snowball" survey. Their study identified a large number of relatively small research groups bound together by a smaller number of what they called "cognitive communities", that is, networks of (groups of) scholars bound together by a common appreciation of central scholars in the field (sources of inspiration), common meeting places, and journals. However, it is possible that, by only including scholars who identified themselves with the term "innovation studies", the study overlooked researchers who work on innovation in contexts where the term is less common.

and orientation of the contributors. Subsequently, references to this core literature are taken from scholarly journals, and with the help of a cluster analysis, these are used to infer the structure of the field and its links with different disciplinary and cross-disciplinary contexts. The final section summarises the lessons learned from the study.

2. Innovation: Identifying the "core" literature

The first step of the research was to identify a number of important reference works (handbooks, textbooks etc.) that could be used to identify the core literature of the field. Six of them, which contained a total of 181 chapters surveying various aspects of innovation, were chosen for the analysis. These six were selected because they were published by high quality publishers, gave a reasonably balanced presentation of the field and satisfied certain criteria with respect to referencing.[6] The book by Dosi et al (1988) aims to present a relatively complete overview of the subject as it was in the 1980s with, as the title indicates, a leaning towards economics. This was not called a "handbook" at the time but had it been published today, it may well have been given that label, although the focus was more towards presenting state-of-the-art research than surveying the field in the traditional sense. The orientation toward economics is something it shares with the later volume by Stoneman (1995). In contrast, Dodgson and Rothwell (1994) and Fagerberg et al. (2004) have a more explicit cross-disciplinary profile. The same is true of the book by Shavinina (2003) which, however, also has a stronger focus on business and management than those mentioned so far. This focus is shared by a highly regarded textbook by Tidd et al. (2005), on the management of innovation.[7]

Some of the 181 chapters were co-authored, so there were 213 authors in total. An attempt was made ex-post to check for the centrality of these authors in the field of innovation studies by investigating the extent to which they were editors or served on the editorial boards/scientific committees of central journals in this field around 1995 and/or 2009. Ten

[6] When this search was conducted, there were only a limited number of handbooks available, the most recent of which was from 2004. However, during the last few years, several new handbooks of relevance for the field have been or are in the process of being published, which means that future analyses based on this methodology may exploit a larger data set than the one used here.

[7] On the publisher's website Professor Clayton M. Christensen of Harvard Business School, author of the "The Innovator's Dilemma" (ranked no. 3 in the list of core innovation literature, see Table 2 below), writes: "This is an extraordinary synthesis of the most important things that are understood about innovation, written by some of the world's foremost scholars in this field." (http://www.wiley.co.uk/wileychi/innovate/).

journals were selected for this test, the five "most important" from the survey by Fagerberg and Verspagen (2009) and another five from the top journals citing the core literature identified through this study (among the top ten citing journals in Table 4 those with the highest impact factors were selected). In the case of Dosi et al. (1988), 62% of the authors had such journal affiliations, while the remaining, with one exception (Shavinina, 2003), were in the 28 – 39 % range. This result is deemed to be quite satisfactory. However, in the case of Shavinina (2003), the similar number was only 6%. Therefore, a sensitivity test for the inclusion of the references from Shavinina (2003) in the sample will be reported (see below).

Table 1. Reference works (11,288 references)

Name of author/editor	**Title**	**Year of publication**	**Publisher**	**Number of chapters (references)**
G. Dosi et al	Technical Change and Economic Theory	1988	Pinter	27 (1,336)
M. Dodgson & R. Rothwell	Handbook of Industrial Innovation	1994	Elgar	35 (1,247)
P. Stoneman	Handbook of the Economics of Innovation and Technological Change	1995	Blackwell	13 (1,630)
L. Shavinina	International Handbook on Innovation	2003	Elsevier	71 (4,303)
J. Fagerberg et al.	The Oxford Handbook of Innovation	2004	Oxford	22 (1,688)
J. Tidd et al.	Managing Innovation	2005(3rd ed.)	Wiley	13 (1,084)

As a next step, all of the references in these books, chapter by chapter, were collected and put together in a database. After the references had been cleaned (for errors of various kinds), 11,288 remained, about 8,100 of which were non-identical, and most of these (92.7 percent) were only mentioned once or twice. The fact that the publications referred to by these references were published at different times implies that the older titles may have a greater chance of being cited than those published more recently. In order to provide a fairer comparison of how many times a set of publications is referred to, a statistic which corrects for this difference was calculated (the J-index).[8] This study focuses on the most commonly

[8] Define maximum citations (E) for any paper or book (B) as one citation per chapter in any source (i.e. 181 chapters in total) published at least one year after the publication of B. If actual citations are A, then the share A*100/E was used as a citation count (J-index).

cited ones which are assumed to be of the greatest general importance. The cut off rate was set at 3.3%, which means that any publication which was cited less than once per thirty chapters (which could potentially have cited it) was not included in the "core literature". The retained sample consisted of 147 publications (see Appendix A for details).

The J-index reflects how important a publication is within innovation studies (according to experts in this area). However, its importance may not be limited to this specific field, but may extend to other specialisations and disciplines. In order to ascertain to what extent this is the case, citations to the core literature in journals included in the Web of Science (ISI – Thomson) were sought, and a staggering number came to light, around 129 thousand citations, more than eight hundred per publication on average. These citations are analysed in more detail in the next section.

Table 2 lists the twenty most important contributions to innovation studies based on the 181 assessments (handbook chapters) included in this study. The name and location of authors, title, publication type, year, J-index and the number of citations per year in the Web of Science are reported for each of these top twenty contributions. Taken together, these contributions cover a wide range of topics of relevance for innovation. Some are theoretical in nature, such as Schumpeter's "The Theory of Economic Development", originally published in 1911 in German and then revised in an English edition in 1934 (number 4 on the list). Many of the ideas, concepts and definitions used today stem from this classic text. However, in the view of experts (i.e. based on the J-index), an even more important theoretical contribution is "An Evolutionary Theory of Economic Change" from 1982 by the Americans Nelson and Winter (number 1 on the list), which combines Schumpeterian and evolutionary perspectives with insights obtained from theories on organisations and human behaviour. Other top-ranked contributions present synthetic overviews and interpretations of current knowledge of innovation, either generally (Freeman's "The Economics of Industrial Innovation", no. 2 on the list), or selected aspects (e.g. Roger's "Diffusion of Innovations", no. 8, von Hippel's "The Sources of Innovation", no. 6, Christensen's "The Innovator's Dilemma", no. 3). A number of highly ranked contributions focus on new concepts or frameworks of analysis and/or their application. For example, this is true of Lundvall's and Nelson's contribution on "National Systems of Innovation" (no. 5 and no. 9 on the list), Dosi's "Technological Paradigms and Trajectories" (no. 11) and Pavitt's "Sectoral Taxonomy" (no. 12).

Table 2. Innovation: Top Twenty Contributions

No	Author	Country	Title	Type	Year	J-index	Citations (ISI/Year)
1	Nelson RR; Winter SG	USA	An Evolutionary Theory of Economic Change	Book	1982	23.8	165.0
2	Freeman C	UK	The Economics of Industrial Innovation	Book	1974	18.8	30.4
3	Christensen CM	USA	The Innovator's Dilemma	Book	1997	16.0	88.4
4	Schumpeter JA	Austria	The Theory of Economic Development	Book	1911	16.0	55.2
5	Nelson RR	USA	National Innovation Systems	Book	1993	15.6	61.0
6	von Hippel E	USA	The Sources of Innovation	Book	1988	14.9	52.6
7	Leonard-Barton D	USA	Wellsprings of Knowledge	Book	1995	14.2	51.2
8	Rogers EM	USA	Diffusion of Innovations	Book	1962	13.8	204.3
9	Lundvall B	Denmark	National systems of innovation	Book	1992	13.6	59.3
10	Porter ME	USA	The Competitive Advantage of Nations	Book	1990	13.6	166.9
11	Dosi G	UK	Technological paradigms and technological trajectories	Journal (RP)	1982	13.3	29.7
12	Pavitt K	UK	Sectoral patterns of technical change	Journal (RP)	1984	13.3	23.2
13	Tidd J; Bessant JR; Pavitt K	UK	Managing Innovation	Book	1997	13.2	25.6
14	Schumpeter JA	USA	Capitalism, Socialism, and Democracy	Book	1942	12.2	79.7
15	Nonaka I; Takeuchi H	Japan	The Knowledge-Creating Company	Book	1995	11.3	176.0
16	Rosenberg N	USA	Inside the Black Box	Book	1982	11.0	37.1
17	Henderson RM; Clark KB	USA	Architectural Innovation	Journal (ASQ)	1990	10.4	49.2
18	Rothwell R	UK	Successful Industrial Innovation	Journal (R&D Man.)	1992	10.4	9.5
19	Freeman C	UK	Technology Policy and Economic Performance: Lessons from Japan	Book	1987	9.9	20.2
20	van de Ven et al.	USA	The Innovation Journey	Book	1999	9.4	15.0

Note: Since the SSCI starts in 1956, ISI/year for the publications prior to this year (Schumpeter 1911, 1942) was calculated as total ISI citations over the number of years from 1956 to 2008.

What clearly emerges from this table is the strong American presence. More than half of the top twenty contributions are American, and this is also true of the larger sample from which the top twenty are taken. However, perhaps what strikes the eye even more is that eighty percent of these top ranked publications are books. If the analysis is extended to include the whole core literature, although the share of journal articles rises somewhat, the majority are still books (see Appendix A). One interpretation of this finding is that it confirms the immature (emerging) nature of the field (Konrad and Pfeffer, 1990; Pfeffer, 1993). However, it may also be that the book format, with its scope for a more holistic analysis, plays a more important role in social sciences than is commonly assumed.

As mentioned above, the sensitivity to the results of excluding the references from Shavinina (2003) from the sample was also investigated. Of the top twenty contributions reported in table 2, seventeen - 85 % - remained in the top twenty after the exclusion of the references from Shavinina (2003). For the whole set of 147 references, the correlation coefficient between the J-indices with and without the references from Shavinina was 0.89. Similar exercises were carried out for the other sources and the results were qualitatively the same. This may be taken as an indication that the picture presented here is pretty robust to the selection of sources.

The final column to the right reports the number of citations in journals per year of these contributions (Web of Science). Although many of the entries are highly cited, there is not a particularly high correlation between the assessments by the experts, as reflected in the J-index, and the number of citations from the Web of Science. This is neither surprising nor worrying. The J-index reflects the importance of the various contributions to the field of innovation studies as assessed by experts in this particular field. However, the number of citations in the Web of Science reflects the impact or popularity of the work in question in the more general world of science. There is no reason to expect these to match. A good example is Thomas Kuhn's outstanding work "The Structure of Scientific Revolutions", which has had more than four hundred citations per year since publication, which is a truly staggering number (see Appendix A). However, this primarily reflects its importance for a whole range of disciplines/fields, extending far beyond social science proper, and has little or nothing to do with its role within innovation studies. In fact, its influence is rather modest in the latter field (no. 60 on the list with a J-index of 5). Thus, its impact is clearly much more strongly felt

outside innovation studies (which explains the exceptionally high number of citations in the Web of Science).

Influential contributors typically publish several important works, often in cooperation with others, and this needs to be taken into account when attempting to identify the most important contributors. For example, while most authors in the sample have one publication which fits the threshold for inclusion in the core literature, five of them have contributed between six and eight publications each, either alone or in cooperation with others. Table 3 ranks the top ten scholars in this area on the basis of their total contributions, how those contributions were assessed by the experts, and adjusted for co-authorship. The "Total J-index" is the (co-author adjusted) sum of the J-indices of an author's works (a similar calculation is used for "Total ISI/Year", which refers to citations in the Web of Science).

Table 3. Innovation: Top 20 contributors

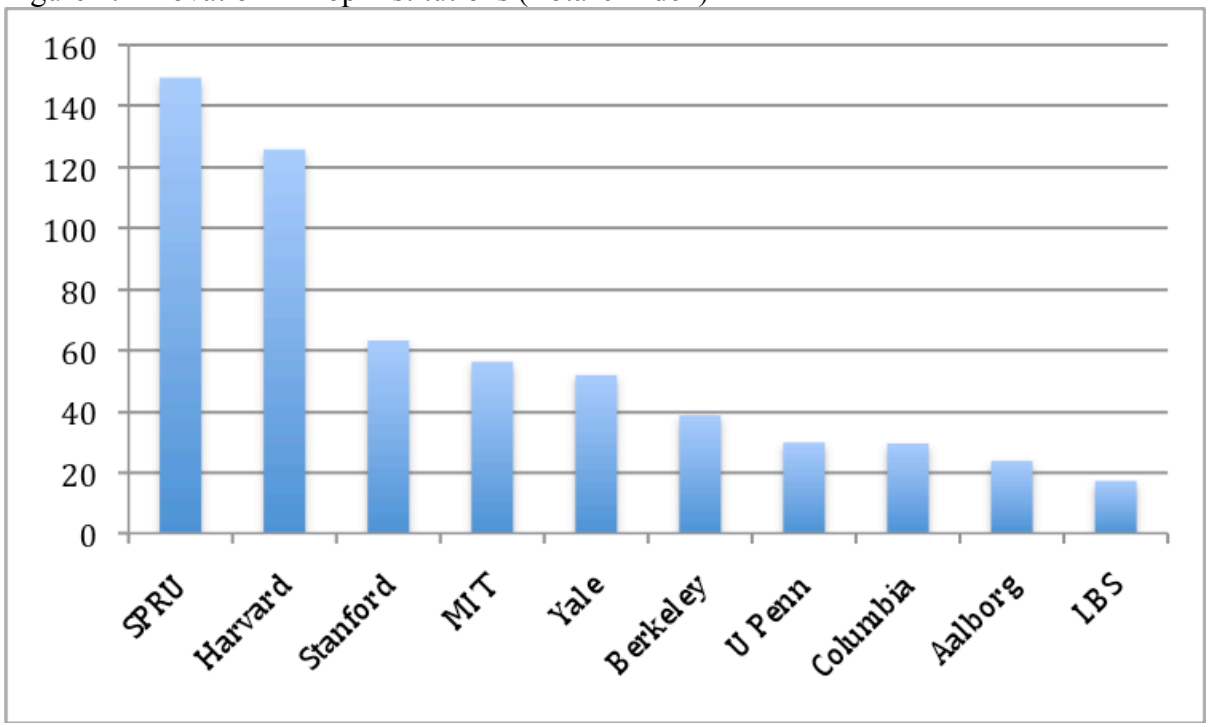
Rank	Authors	Affiliation(s)	Country	Total J-index	Total ISI/year
1	Freeman C	SPRU	UK	42.0	76.8
2	Nelson RR	Columbia/Yale/RAND	USA	40.6	172.9
3	Rosenberg N	Stanford	USA	40.2	97.4
4	Schumpeter JA	Harvard/Graz	USA/ Austria	34.3	157.3
5	Pavitt K	SPRU	UK	25.4	40.8
6	Dosi G	SPRU	UK	24.0	74.1
7	Lundvall B	Aalborg/OECD	Denmark/ France	23.8	84.2
8	Mansfield E	U Penn.	USA	16.8	49.1
9	Perez C	SPRU	UK	16.6	21.9
10	Winter SG	Yale	USA	16.2	96.9
11	Christensen CM	Harvard/Graz	USA	16.0	88.4
12	Rothwell R	SPRU	UK	16.0	14.9
13	Teece DJ	Berkeley	USA	16.0	105.9
14	Griliches Z	Harvard	USA	15.5	80.9
15	von Hippel E	MIT	USA	14.9	52.6
16	Leonard-Barton D	Harvard	USA	14.2	51.2
17	Rogers EM	Ohio State U.	USA	13.8	204.3
18	Porter ME	Harvard	USA	13.6	166.9
19	Hamel G	LBS	UK	13.4	102.8
20	Williamson OE	U Penn./Yale	USA	12.7	401.5

Note: Since the SSCI starts in 1956, total ISI/year for Schumpeter is the sum of total ISI/year of his three books (1911, 1939, 1942), which was calculated as total ISI citations over the number of years from 1956 to 2008 (see Appendix A).

When judged by the experts (Total J-index), four contributors stand out as being particularly influential, namely, Freeman, Nelson, Rosenberg[9] and Schumpeter, followed at a distance, by Pavitt, Dosi and Lundvall. However, ranking scholars is a risky business. It is reassuring, therefore, that the web-based worldwide survey of more than one thousand researchers within "innovation studies" (Fagerberg and Verspagen, 2009) points to exactly the same seven scholars as being the most important "sources of inspiration" for scholarly work in this area. It can hardly be a coincidence that two investigations into the same issue, based on totally different data and methods, lead to almost the same result.

Figure 2 ranks the ten top research institutions in this area based on the scientific contributions of their employees and the importance of these contributions as assessed by experts (the J-index). The calculation shows that SPRU (at the University of Sussex, UK), home to such influential scholars as Freeman, Pavitt and (at some point) Dosi, is well ahead of the others. The second to the seventh place following SPRU are all occupied by prestigious US universities (headed by Harvard).

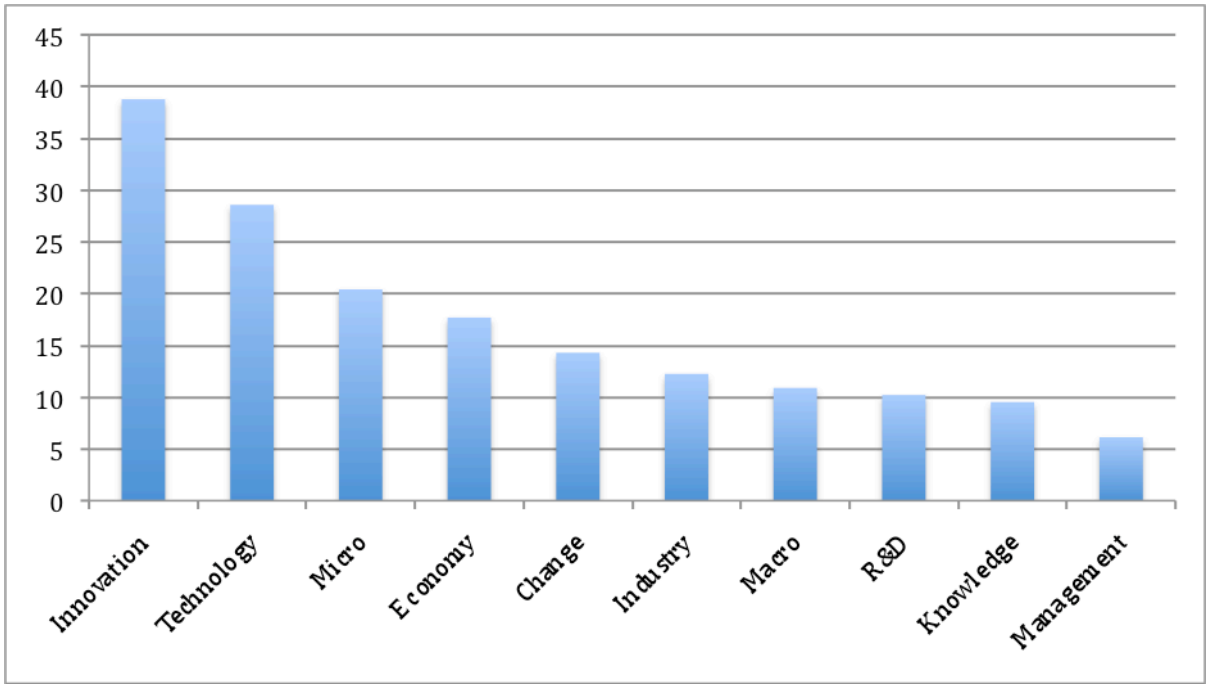
Figure 2. Innovation – Top Institutions (Total J-index)



[9] The high position of the US economic historian, Nathan Rosenberg, may seem surprising given that he has no work among the top ten. However, the explanation is that he is the most productive of all authors on the list with eight publications above the threshold for inclusion in the core literature.

Another way to characterise this knowledge base is to examine the thematic priorities. It would clearly have been preferable to analyse this by means of a text analysis of abstracts (or entire texts). But the core literature mainly consists of books (which do not have abstracts and cannot be accessed electronically), so this was not a practical option. In fact, most of the journal articles, especially the older ones, did not have abstracts either. Therefore, the titles were chosen for analysis, with a focus on commonly used terms, or "keywords". This methodology is of course not ideal, since titles do not always match the content in a perfect way. Still it seems reasonable to assume that in most cases titles reveal important information about the focus of the author(s). The titles were divided into words, and the number of times a specific word appeared was counted. Similar words, such as "economic", "economy" etc. were grouped together, while commonly used, but uninteresting, words such as "and" or "why" were excluded. As was perhaps to be expected, the most common keyword was "innovation". Figure 3 illustrates that 39% of the core publications have innovation in the title. "Technology" is another commonly used term, shared by 29% of the contributions. As for the level of analysis, the firm level ("micro") was clearly the most popular. 20% have "firm" (or corporation, company, etc.) in the title, far more than, say, "industry" (12%) or the regional, national or global level ("macro"), which accounted for 11%.

Figure 3. Thematic focus, percentage



3. Innovation: Knowledge users

This section will move from the knowledge producers, and the experts assessing their work, to the users of this knowledge. The use of scientific knowledge leaves trails, for instance in the form of citations, and these will be exploited here. As mentioned previously a search was made for citations to the full sample of 147 contributions in the scholarly journals included in the Web of Science (ISI Thomson), and a note was made of the scientific fields of these journals, as reflected in the so-called subject-areas.[10] In this way, it was possible to make a connection between each citation and one or more scientific field (a journal may cover several subject-areas). By taking all citations to a particular contribution into account, a quantitative assessment may be obtained of how this contribution is used by scholars in different scientific fields and/or disciplines.

A total of around 6,000 journals (in all areas of science) cited this literature. However, most of them cited very little, i.e. one citation per year or less. 10% of the journals contained three quarters of the citations. Table 4 below lists the 20 most important citing journals, which collectively account for about one quarter of all citations. As is evident from the table, authors in Research Policy are especially eager users of this literature, representing twice as high a share as the next entry on the list, Strategic Management Journal. Many of the top citing journals belong to the fields of management and business, which indicates that scholars in management and business studies are important users of this knowledge. Nonetheless, the list of top journals also includes a journal which focuses on regional issues and, toward the end of the top twenty, two (heterodox) economics journals. It is worth noting that, although many of the top scholars in this area have a background in economics (Fagerberg and Verspagen, 2009), mainstream economics journals do not appear to be among the prime users of this literature.

[10] ISI categorises journals, and hence articles, based on subject-area(s), which may be disciplines or "specialisms" within or across disciplines.

Table 4. Knowledge users: Top twenty Journals

Rank	Journal	Percent	Cumulative Percent	Subject-area(s)
1	Research Policy	4.0	4.0	Management; Planning & Development
2	Strategic Management Journal	2.1	6.1	Business; Management
3	International Journal of Technology Management	1.8	7.9	Engineering, Multidisciplinary; Management; Operations Research & Management Science
4	Technovation	1.5	9.4	Engineering, Industrial; Management; Operations Research & Management Science
5	Technological Forecasting and Social Change	1.2	10.6	Business; Planning & Development
6	R and D Management	1.1	11.7	Business; Management
7	Journal of Management Studies	1.1	12.7	Business; Management
8	Organisation Science	1.1	13.8	Management
9	Academy of Management Review	1.0	14.8	Business; Management
10	Technology Analysis and Strategic Management	.9	15.7	Management; Multidisciplinary Sciences
11	Journal of Product Innovation Management	.9	16.5	Business; Engineering, Industrial; Management
12	Management Science	.8	17.4	Management; Operations Research & Management Science
13	Regional Studies	.8	18.2	Environmental Studies; Geography
14	Organisation Studies	.8	19.0	Management
15	Academy of Management Journal	.8	19.8	Business; Management
16	Industrial and Corporate Change	.8	20.6	Business; Economics; Management
17	IEEE Transactions on Engineering Management	.7	21.3	Business; Engineering, Industrial; Management
18	Cambridge Journal of Economics	.7	22.0	Economics
19	Journal of Evolutionary Economics	.6	22.6	Economics
20	Administrative Science Quarterly	.6	23.2	Business; Management

Although taking note of the top journals is quite illustrative, a more precise description of the disciplinary orientation of the knowledge users in this area may be obtained by using the approach described above, i.e. to take account of the information about subject-area categories. However, it should be noted that the subject-area categories, of which there are several hundred, have been developed by ISI over the years, and do not always cover disciplines or scientific fields (within or across disciplines) in a way which is appropriate for research. For example, the extent to which specialities within, or across, disciplines are covered varies greatly, and relatively recent, although vibrant, fields, such as innovation studies, may not be covered at all. Thus, journals focusing on a novel area such as innovation

studies, to the extent that such journals are included at all, will have to be found in other categories. For example, the quite ill-defined "planning and development" category is home to Research Policy, the most important journal in this area. Moreover, in some cases the subject-areas are fairly aggregated (economics for instance), while in others, a discipline may be divided into many different categories (psychology may serve as example of this).

For the purpose of this research, it would be useful if the subject-areas could be aggregated into a smaller number of groups of like-minded scholars. To approach this objective, the most obvious adjustments were made first (such as merging all the different subgroups within psychology into one group). In a second step the citation patterns of the 35 biggest subject-areas (those with 500 citations or more each), which altogether accounted for more than 90 % of the total citations to the core literature, were analysed to determine whether or not some of these could be meaningfully aggregated into larger wholes. Particular attention was paid to how scholars in the different subject-areas used the core literature in innovation studies, and if the citation patterns (preferences) of two subject-areas were strongly correlated, this was taken as an argument for merging the two. Similarly, if the patterns turned out to be rather different, this was seen as a reason for keeping them apart. The results of this analysis (see Appendix B) indicate that, while some disciplines or scientific fields, such as economics, political science and "planning and development" have rather distinct citation profiles, these differences are almost negligible in other cases. In this way, it was possible to identify a large group of like-minded users in disciplines such as education, psychology, philosophy and sociology, which was aggregated into a common "Social sciences and humanities" group. Similarly, this grouping exercise found a cluster of (strongly related) scientific fields focusing on health, and another which incorporated information and computer science, as well as a third which emphasised spatial issues (urban studies, geography and environmental studies).[11] Figure 4 provides an illustration of how the users are divided across the ten largest groups, which collectively account for 89% of the total citations to the core literature in the Web of Science.

[11] Readers interested in more details may consult Appendix B to this paper.

Figure 4. Knowledge users: Disciplinary orientation (Top 10 subject-areas), percentage

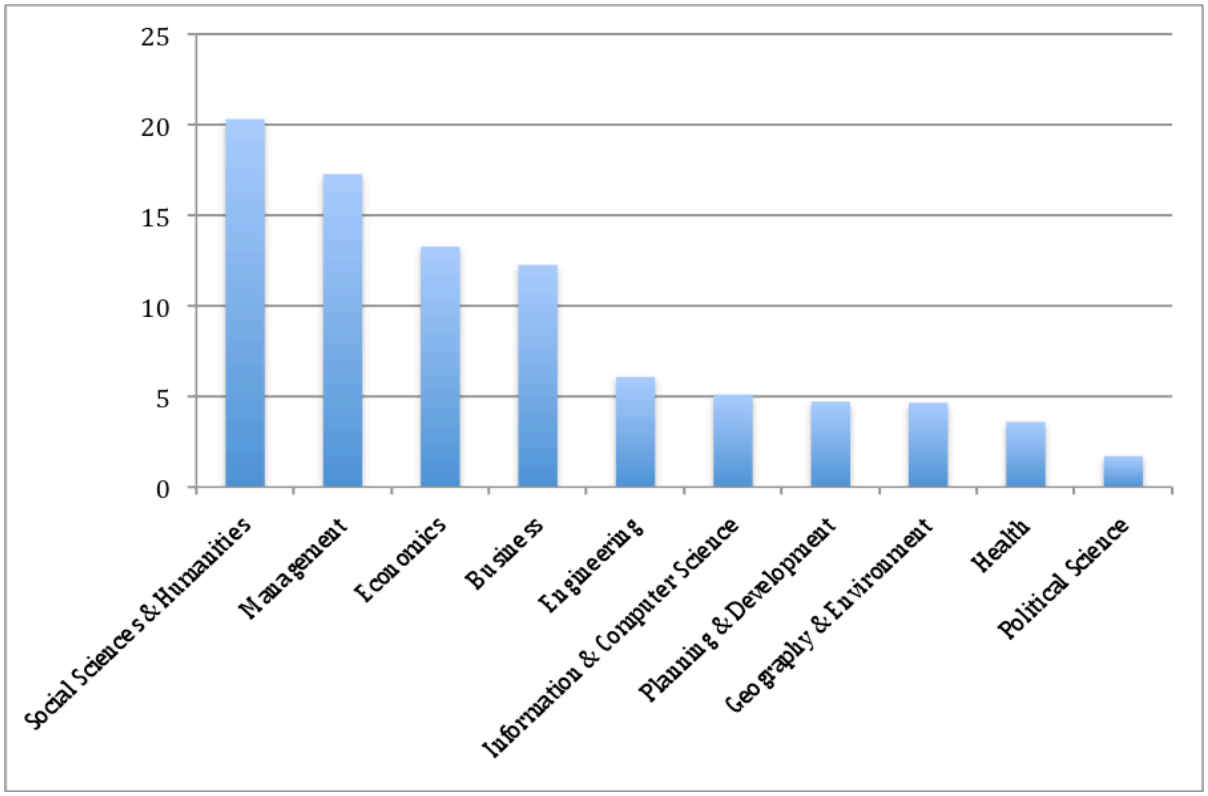


Figure 4 confirms that the core literature is used in a broad array of disciplines and scientific fields. The composite "Social sciences and humanities" group is the largest, with 20% of the users, and this is followed by Management (17%), Economics (13%) and Business (12%).[12] Together the latter three areas, which all focus on economic activities in one way or another, account for almost one half of the total number users. There are also many users in other areas of social science (not included in the larger composite), the largest of which is the cross-disciplinary "Planning and Development" field. Although the overwhelming number of users (close to ninety percent) is within social sciences (broadly defined), there is also a significant number in areas such as engineering and natural science.

A better impression of the interest shown by researchers from different fields for the literature on innovation may be obtained by adjusting the shares reported in Figure 4 for differences in the size of subject areas. This may be done by dividing these shares with the shares of the same subject areas in all citations in the Web of Science. Hence, if the users within a specific

[12] It is sometimes suggested that such numbers may reflect differences in citation intensity between fields. This was, therefore, checked. The results indicate that, if such differences were adjusted for, Management, Economics and Business would be of about the same size (11-13%). The strongest increases (but not enough to alter the ranking reported in Figure 4) would be observed for Engineering and for Information and Computer Science since researchers in these areas tend to cite significantly less than the average.

subject area show an above average interest in the literature on innovation, the adjusted figure (Specialization) will be above one and vice versa. For reasons that had to do with data availability this calculation was made for the period 2003-2008 only. The results (Figure 5) indicate that the reason why the composite "Social sciences and humanities" group has the largest share is not that users in this area are particularly fond of the core literature but that there are many scholars and hence citations in this area. For Management it is the other way around, it is a relatively small area in terms of citations, but users within this area are more than twelve times as likely than the "average scholar" to cite the core literature. Also users within the Planning and Development and Business fields are eager users of this literature. The same holds, although to a lesser extent, for Economics.

Figure 5. Specialisation of knowledge users (6-year average, 2003 – 2008)

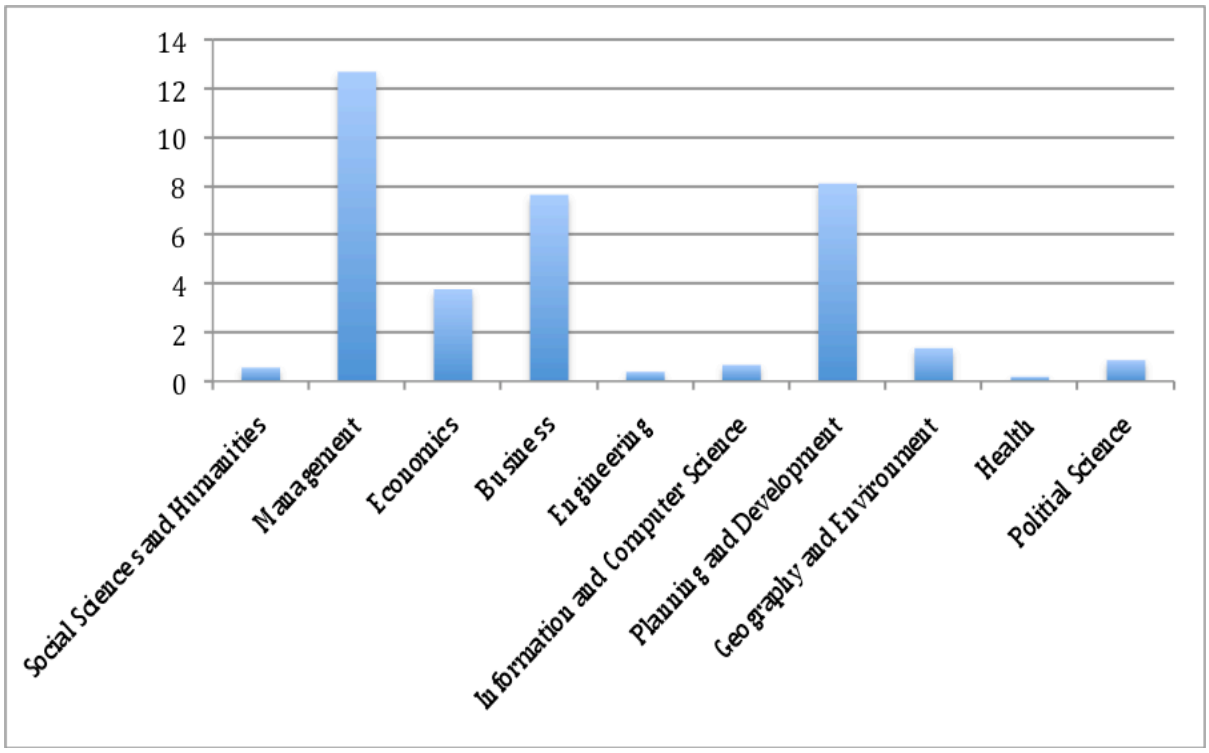
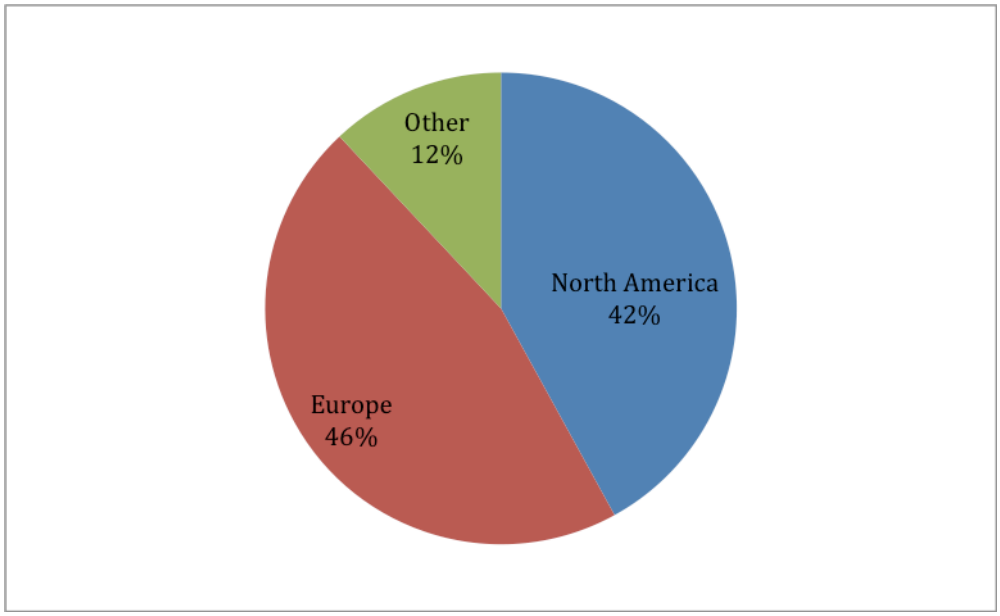


Figure 6 attempts to shed light on the geographical composition of the knowledge users. Unfortunately, the data does not allow for a complete analysis of authors and their locations, since much of this information is missing, especially for the years prior to 1998 and for multi-authored papers. Therefore, the figure is based on a subset of 28,917 single-authored papers published after 1997. Although there is no reason to believe that the locations of authors of single-authored papers deviate in a systematic way from those of other authors, lack of information of earlier years means that it is not possible to explore changes which may have

occurred in the geographic spread of the knowledge users during the period covered by this study. Figure 6 shows that the largest group of users is to be found in Europe, closely followed by North America and, at a distance, the rest of the world. That innovation studies is largely a European-American affair, with Europe as the largest hub, is consistent with the results from the web-based survey of innovation scholars conducted by Fagerberg and Verspagen (2009). However, the division between Europe and North-America appears to be more even than that indicated by their study.

Figure 6. Knowledge users: Where they work



4. Exploring the structure of the knowledge base

This section will provide an exploration into the cognitive characteristics of the field in the form of a cluster analysis of the core literature. The analysis particularly focuses on three dimensions of this evidence: the *thematic orientation* of the core literature, its *disciplinary orientation* and various characteristics of the *generation and selection processes* that take place.

In terms of the thematic character of the core literature, the occurrence of "key-words" reflecting the orientation of the contribution towards various issues is used (the ten most commonly used terms were selected, see Figure 3 above). The value 1 is assigned to a keyword variable if the contribution has the respective keyword in the title. In terms of the

disciplinary profiles of these contributions, the ten most important subject-areas or groups are similarly used (Figure 4). This variable is measured as the share of citations from a particular subject-area in all citations to the contribution. As for the production and selection environments, a number of variables (five in total) are used. These variables are elaborations of the information presented in the previous sections. Firstly, the analysis includes a variable which reflects the orientation of the contribution in respect of innovation studies proper compared to the scientific world in general (INSIDER). This variable, which is the ratio of the J-index to journal-citations (ISI) per year, is high if the contribution is considered to be more relevant in innovation studies than elsewhere, and vice versa.[13] The analysis also includes a variable to measure the quality of the research environment with which the author(s) of the various contributions were affiliated (at the time of publication). This variable (EXCELLENCE) is measured as the sum of the J-indices of all publications in the core literature emanating from that particular research environment (adjusted for co-authorship). Since one research environment (SPRU) appears to be much more productive than the others, and has played an important role in the development of the field, a separate effect from being affiliated with that is allowed.[14] The analysis also considers that some journals, such as Research Policy and Strategic Management Journal, are very prestigious in the context of innovation studies, and that citations from such sources may signal particularly high quality and/or relevance. These variables (RP and SMJ) are calculated as the share of citations from articles published in Research Policy and Strategic Management Journal, respectively, in all citations to the contribution.

A cluster analysis is an exploratory tool which sorts similar objects into the same group (cluster), so that the degree of association between objects is maximal if these belong to the same group, and minimal otherwise. The purpose of a cluster analysis is primarily to explore structures in the data and, as pointed out by Hair et al. (2010), the informed judgement of the researcher is essential when deciding the number of clusters. Various methods are available, but not all of these allow for a mix of continuous and categorical variables in the analysis as is required in the present case. The Two-step cluster method in SPSS (version 11.5 and later) fulfils this requirement, and was, therefore, chosen for the analysis. As the name suggests, this

[13] A small positive value (0.0256) was added to the denominator to avoid problems caused by values for ISI/year (range-standardised) close to zero.

[14] The SPRU variable equals one if all of the authors of a publication were affiliated with SPRU at the time of publication. If the authors had different affiliations, the number is fractionalised.

method has two steps. In the first step, the objects are aggregated into a large number of small clusters, and in the second step, these clusters are merged into a limited number of larger clusters by means of agglomerative hierarchical clustering. According to traditional statistical criteria,[15] the three best cluster solutions are the ones with two, three, and four clusters (see Appendix C for details). Since this research is interested in an in-depth analysis of the structure reflected in the data, the most detailed of these three solutions is described in the following (see Table 5). It should be noted, moreover, that due to the hierarchical clustering method, the two and three cluster solutions are mere aggregations of the four cluster solution.

The largest cluster, consisting of 56 contributions, focuses to a large extent on issues related to "Economics and Technology", which is also the name chosen for this cluster. The contributors to this literature are mainly Americans, working in top US universities, while the users of this knowledge are much more evenly distributed geographically (close to the sample average). The largest citing field is Economics, and the most central work, as assessed by the experts (the J-index), is Nelson and Winter's "An Evolutionary Theory of Economic Change" published in 1982, which is normally regarded as being very heterodox (and is cited much more outside economics than within).[16] Hence, the term "economics" does not necessarily imply a signal that this literature is mainstream. For example, there are four economics journals among the ten most important journals citing this cluster, of which only one is clearly mainstream (American Economic Review), while two are more heterodox (Cambridge Journal of Economics and Journal of Evolutionary Economics). The remaining is Small Business Economics, which focuses mainly on entrepreneurship and small businesses.

[15] Various criteria are available. This study reports the BIC (Schwarz Bayesian Information Criterion) and Ratio of Distance Measures (see Appendix C for details).

[16] According to Meyer (2001), Nelson and Winter's book has many more citations in management and organisational science journals than in economics journals. The likelihood of a citation was six times higher in the Strategic Management Journal than in the American Economic Review.

Table 5. Clustering the literature

Cluster	Core Innovation Studies	Economics & Technology	Outsiders	Innovation Management
Works (authors)	28 (23)	56 (59)	29 (47)	34 (57)
Thematic focus	Innovation (75%) Technology (36%)	Technology (39%) Economy (34%)	Firms (52%) Innovation (21%)	Innovation (76%) Firms (38%)
Most central work (J-index)	Freeman 1974	Nelson and Winter 1982	Nonaka and Takeuchi 1995	Christensen 1997
Most cited work (ISI/year)	Nelson 1993	Williamson 1985	Kuhn 1962	Rogers 1962
Most important affiliation	SPRU (57%)	Harvard (21%) Stanford (12%)	MIT (9%) Berkeley (7%)	Harvard (17%) SPRU (15%)
Location of authors	Europe (77%) North America (21%)	North America (75%) Europe (24%)	North America (67%) Europe (25%)	North America (64%) Europe (35%)
Most important citing journal	Research Policy	Research Policy	Strategic Management Journal	Research Policy
Largest citing field	Management (21%) Economics (16%)	Economics (29%) Social Sciences & Humanities (16%)	Social Sciences & Humanities (30%) Management (16%)	Management (25%) Business (18%)
Specialisation	Planning and development	Economics	Social Sciences & Humanities / Information & Computer Science	Management / Business / Engineering
Location of citers	Europe (66%) North America (20%)	Europe (45%) North America (44%)	North America (52%) Europe (37%)	North America (50%) Europe (38%)
Insider (normalised mean 0-1)	0.36	0.15	0.06	0.24
Excellence (normalised mean 0-1)	0.65	0.32	0.13	0.38

The second largest cluster consists of 34 works united by a strong focus on innovation in firms. In fact, more than three quarters of the contributions in this category have the term "innovation" in the title. As in the previous case, the knowledge users are fairly geographically widespread, while the producers are predominately Americans. The largest citing field is Management (followed by Business), and the most central work is Christensen's "The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail" published in 1997, a topical book from management literature. Another characteristic feature of this literature is that all of the most important journals which cite it have Management or Business among their subject-areas. Therefore, the name "Innovation Management" was chosen for this cluster.

The two remaining clusters are approximately equal in size, but otherwise, they are quite different. The cluster called "Core Innovation Studies" (28 works) also focuses very strongly on innovation (three quarters of the works in this category have "innovation" in the title) and, like the largest cluster mentioned above, on "technology". In contrast to the previous cases, the knowledge producers in this cluster are predominantly Europeans. In fact, more than half of the contributors had a SPRU affiliation at the time of publication, so this cluster is clearly centred on SPRU, traditionally the most prestigious specialised research environment in this area. It is perhaps no surprise that the most central work in this literature was written by Christopher Freeman, the founder of the SPRU. What may be surprising is that, in this case, not only the knowledge producers, but also the knowledge users, are mainly Europeans. The largest citing field is, as in the previous case, Management, closely followed by Economics, and Planning and development. However, in relative terms, when differences in the size of citing fields are adjusted for, it is the latter field which contributes most to differentiating this from the other clusters. The cluster also has a very high "insider" index, which indicates that this literature is much appreciated by experts in this specific field.

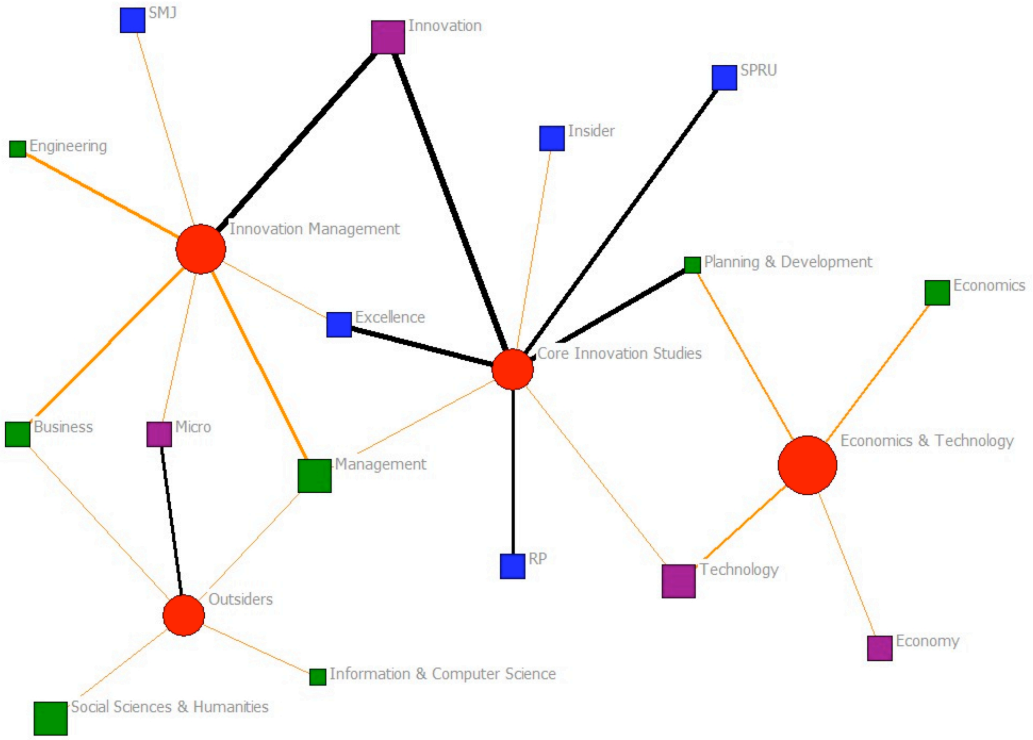
Finally, there is a cluster with 29 contributions, which has been labelled "Outsiders". This label has been chosen partly because the thematic focus in this case is more on firms in general than, say, their technological activities or innovative performances. However, it also has to do with the fact that, while they are highly cited in the Web of Science (ISI/year), many works in this cluster are much less central to the particular field being studied here (as reflected in the J-index). This is reflected in a record low "insider" index (close to zero) for this cluster, which confirms that, on the whole, this literature is much more orientated to other

disciplines and scientific fields. Another characteristic feature which contributes to differentiating this cluster from the others is that the most important citing field in this case is the composite "Social sciences and humanities" group. In fact, the majority of citations from Social sciences and humanities were made to the literature in this cluster.

Figure 7 summarises some of the above information in the form of a network graph.[17] The literature clusters are shown as circles of various sizes, depending on the number of works in the cluster, and the variables taken into account in the cluster analysis are treated as being possible links between clusters. For example, if two literature clusters share a thematic focus (keyword), this constitutes a link between the two. In the cluster analysis, the numerical value of these variables was normalised to a range between zero and unity, with unity indicating a very strong connection, and zero no connection at all. Since there will always be a certain amount of variety of the characteristics within a cluster, there will normally be many weak links (close to zero), and a smaller number of stronger links indicating the existence of more robust relationships between the cluster and the variables. If all links are taken into account, independent of their strength, all clusters will appear to be closely connected. However, when the weaker, not so important, links are removed, a clearer structure may emerge. This is why the weaker, not so typical links, have been eliminated in Figure 7, and the focus has been placed on the more significant ones (by setting the "cut-off" rate to one third in the zero-unity range).

[17] This network graph was produced using a spring-embedding method in Ucinet/Netdraw. The input data source is the results of the cluster analysis (the four cluster case, see Appendix C).

Figure 7. Relationships between literature clusters and variables (cut off = 0.33)



Note: Literature clusters are denoted by red circles of different sizes, based on the number of works in the cluster (see Table 5). Disciplinary orientation variables are denoted by green squares of different sizes, based on the amount of citations to the 147 core innovation literature from the (composite) subject-area concerned (see Figure 4). Thematic orientation variables are denoted by purple squares of different sizes, based on the share of the 147 core innovation literature that have the keyword concerned in the title (see Figure 3). Blue squares (all of the same size) represent the remaining variables, which include Insider, Excellence, SPRU, RP and SMJ. The strength of the relationships between the clusters and the variables is indicated by line thickness and colour (strong and medium links are in black and orange colours, respectively).

As shown in Figure 6, the cluster called "Core Innovation Studies" lives up to its name: Its knowledge (and those who produce it) constitutes a link between the "Economics & Technology" and the "Innovation Management" and "Outsiders" clusters. Without this the entire knowledge base would fragment into an economics part and a management/outsider part with little, if anything, in common. Another way to illustrate the integrative role played by "Core Innovation Studies" is to examine the overlap in authorship between the literature clusters. As mentioned, some prolific writers contributed several works, and sometimes also to more than one cluster. However, there were big differences between the four clusters in this respect. While, in the "Core Innovation Studies", 61% of the authors had also contributed to

the other literature clusters, the similar shares for the authors of the other clusters were much lower, from 13% ("Outsiders") to 21-22% in the two remaining cases.

5. Concluding remarks

A century ago the innovation theorist, Joseph Schumpeter, reflecting the state of social sciences, pointed out that "individual social sciences ... did not arise through the logical division of some originally unified realm of knowledge; they arose by chance ... from some particular problem or method" (Schumpeter, 1910/2003, as cited in Andersen, 2009:312). From this perspective, social sciences should be analysed as being an evolving structure, constantly challenged by new problems and the need for new knowledge. However, such evolutionary processes are often slow to materialise and easy to lose track of. Therefore, an observer of social science at a particular point in time may be forgiven for thinking that the structure, with disciplines, journals, associations, departments etc, has been pretty stable. Yet, it is boiling beneath the surface! New scientific fields or specialisations, within or across disciplines, are emerging all the time in response to problems which arise and the need for new knowledge. In fact, many, if not most, of the several hundred "subject-areas" which exist in the Web of Science are related to the rise of such fields or specialisations within, but increasingly also across, established disciplines.

Since such emerging areas of knowledge usually lack most of the institutions and organisations which characterise established disciplines, they may be difficult to study, and this is also true of the field under scrutiny here, i.e. innovation studies. When confronted by this challenge, the present study chose to study the characteristics of the field "through the eyes of experts". Having identified the core contributors and contributions to the field in this way, and analysed their characteristics, this knowledge was complemented by a collection of information about the users of this literature (as reflected in citations in scholarly journals). In this way, it was possible to throw some light on the nature of the relationship between the emerging field of innovation studies and other currents (including the established disciplines) within the world of science.

This study demonstrates that a sizeable amount of literature on innovation has been developed, primarily from the 1960s onwards, with a particularly strong growth during the last two decades. Thus, although innovation is not at all a new phenomenon, societal interest

in it is clearly much larger now compared with a few decades or half a century ago. In response to this change, researchers from a variety of backgrounds took up the challenge and, as a result, a broad knowledge base on innovation, as viewed from different angles and perspectives, has emerged. The production of this knowledge has been particularly strong in the US and the UK. The position of the latter in this field is, to a large extent, related to the emergence in the 1960s of SPRU at the University of Sussex, and the academic entrepreneurship of Christopher Freeman, who is the single most important contributor to innovation literature, according to the assessments of experts in this area.

Although the central literature in this area is mainly produced by scholars from the US and the UK, with affiliations to a limited number of strong research environments in those countries, the users of this literature are much more geographically widespread. Moreover, the disciplinary orientation of these users, as it is revealed based on the subject-areas of journals in which their works are published, clearly emphasises the multi-disciplinary and cross-disciplinary characteristics of the field, with users within a range of disciplines and fields extending far beyond social science proper. Surprising to some, perhaps, only one of seven users is an economist in the accepted meaning of the term. It deserves to be mentioned, though, that there are many users in related fields who also focus on economic matters in some sense or another. This includes fields such as management, business, planning and development, geography etc. Therefore, in this broader sense, the share of "economics" users would be larger, around one half of the sample. Such a perspective on economics would be consistent with the views of Schumpeter, who argued in favour of a very broad definition of the subject (Andersen, 2009).

To some extent, what the research presented here has demonstrated is that there are two main "poles" in innovation literature, one of which focuses on innovation in firms, and is popular with scholars in business and management, and another which emphasises the role played by technology and innovation in economic and social change more generally. The latter is particularly appreciated by scholars with a background in economics and other social sciences. However, a more detailed analysis reveals that it is possible to distinguish a third branch of research which is positioned in between the two main poles, and which contributes significantly to keeping the different parts of the knowledge base connected. As pointed out earlier, without this research, the entire knowledge base would fragment into an economics and a management orientated part with few, if any, links. Therefore, from a systems point of

view, the cross-disciplinary research conducted within "Core Innovation Studies" performs an important (integrative) function. Arguably, the future prospects for this scientific field may depend, to a large extent, on this (integrating) function also being performed in the years to come. An important question for further research is whether this can be achieved in the same way as before, or whether it will require a stronger institutional and organisational structure. It would also be interesting to compare the development of innovation studies with other emerging scientific fields to see how such integration has been conducted there, and whether there are some general insights into the evolution of (social) science to be obtained.

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Appendix A

Table A. Core innovation literature (ranked by J-index)

No.	Author	Country	Title	Type	Year	J-Index	ISI/ year	Cluster No.*
1	Nelson RR; Winter SG	USA	An Evolutionary Theory of Economic Change	Book	1982	23.8	165.0	2
2	Freeman C	UK	The Economics of Industrial Innovation	Book	1974	18.8	30.4	1
3	Christensen CM	USA	The Innovator's Dilemma	Book	1997	16.0	88.4	4
4	Schumpeter JA	Austria	The Theory of Economic Development	Book	1911	16.0	55.2	2
5	Nelson RR	USA	National Innovation Systems	Book	1993	15.6	61.0	1
6	von Hippel E	USA	The Sources of Innovation	Book	1988	14.9	52.6	4
7	Leonard-Barton D	USA	Wellsprings of Knowledge	Book	1995	14.2	51.2	4
8	Rogers EM	USA	Diffusion of Innovations	Book	1962	13.8	204.3	4
9	Lundvall B	Denmark	National systems of innovation	Book	1992	13.6	59.3	1
10	Porter ME	USA	The Competitive Advantage of Nations	Book	1990	13.6	166.9	2
11	Dosi G	UK	Technological paradigms and technological trajectories	Journal (RP)	1982	13.3	29.7	1
12	Pavitt K	UK	Sectoral patterns of technical change	Journal (RP)	1984	13.3	23.2	1
13	Tidd J; Bessant JR; Pavitt K	UK	Managing Innovation	Book	1997	13.2	25.6	4
14	Schumpeter JA	USA	Capitalism, Socialism, and Democracy	Book	1942	12.2	79.7	2
15	Nonaka I; Takeuchi H	Japan	The Knowledge-Creating Company	Book	1995	11.3	176.0	3
16	Rosenberg N	USA	Inside the Black Box	Book	1982	11.0	37.1	2
17	Henderson RM; Clark KB	USA	Architectural Innovation	Journal (ASQ)	1990	10.4	49.2	4
18	Rothwell R	UK	Successful Industrial Innovation	Journal (R&D Man.)	1992	10.4	9.5	1
19	Freeman C	UK	Technology Policy and Economic Performance: Lessons from Japan	Book	1987	9.9	20.2	1
20	Van de Ven et al.	USA	The Innovation Journey	Book	1999	9.4	15.0	4
21	Kline SJ; Rosenberg N	USA	An Overview of Innovation	Chapter	1986	9.4	15.0	1
22	Rosenberg N	USA	Perspectives on Technology	Book	1976	8.8	19.1	2

23	Hamel G	UK	Leading the Revolution	Book	2000	8.5	20.1	4
24	Lundvall B	Denmark	Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation	Chapter	1988	8.4	17.7	1
25	Teece DJ; Pisano G	USA	The Dynamic Capabilities of Firms: an Introduction	Journal	1994	8.4	18.3	4
26	Utterback JM	USA	Mastering the Dynamics of Innovation	Book	1994	8.4	42.1	4
27	Burns T; Stalker GM	UK	The management of innovation	Book	1961	8.3	55.7	3
28	Teece DJ	USA	Profiting from technological innovation: implications for integration, collaboration, licensing and public policy	Journal	1986	8.3	46.5	4
29	Cohen WM; Levinthal DA	USA	Absorptive capacity: A new perspective on learning and innovation	Journal	1990	7.8	124.3	4
30	Tushman ML; Anderson P	USA	Technological discontinuities and organisational environments	Journal	1986	7.7	42.6	4
31	Leifer R; McDermott CM; O'Connor GC; Peters LS; Rice MP; Veryzer RW	USA	Radical Innovation: How Mature Companies Can Outsmart Upstarts	Book	2000	7.5	10.6	4
32	Rothwell R; Freeman C; Horsley A; Jervis VTP; Robertson AB; Townsend J	UK	SAPPHO Updated: Project SAPPHO Phase II	Journal	1974	7.2	8.8	4
33	Clark KB; Fujimoto T	USA, Japan	Product development performance: strategy, organisation, and management in the world auto industry	Book	1991	7.1	53.9	4
34	Womack JP; Jones DT; Roos D	USA, UK	The machine that changed the world: based on the Massachusetts Institute of Technology 5-million dollar 5-year study on the future of the automobile	Book	1990	7.1	100.4	3

35	Freeman C; Clark J; Soete L	UK	Unemployment and Technical Innovation: A Study of Long Waves and Economic Development	Book	1982	6.6	11.1	1
36	Nelson RR; Winter SG	USA	In search of useful theory of innovation	Journal	1977	6.6	13.4	1
37	Schmookler J	USA	Invention and Economic Growth	Book	1966	6.6	19.0	2
38	Williamson OE	USA	Markets and hierarchies: analysis and antitrust implications: a study in the economics of internal organisation	Book	1975	6.6	168.8	3
39	Tushman M; O'Reilly CA	USA	Winning through innovation: a practical guide to leading organisational change and renewal	Book	1997	6.6	17.2	4
40	Cohen WM; Levinthal DA	US	Innovation and Learning: The Two Faces of R & D	Journal	1989	6.5	43.3	2
41	Mowery DC; Rosenberg N	USA	Technology and the Pursuit of Economic Growth	Book	1989	6.5	14.7	2
42	Arrow KJ	USA	Economic welfare and the allocation of resources for invention	Chapter	1962	6.1	26.0	2
43	Perez C	UK	Structural Change and Assimilation of New Technologies in the Economic and Social Systems	Journal	1983	6.1	6.1	1
44	Piore MJ; Sabel CF	USA	The second industrial divide: possibilities for prosperity	Book	1984	6.1	108.2	2
45	Schumpeter JA	USA	Business cycles: a theoretical, historical, and statistical analysis of the capitalist process	Book	1939	6.1	22.4	2
46	Williamson OE	USA	The economic institutions of capitalism: firms, markets, relational contracting	Book	1985	6.1	232.7	2
47	Hamel G; Prahalad CK	USA, UK	Competing for the Future	Book	1994	5.9	64.8	3
48	Saxenian A	USA	Regional Advantage: Culture and Competition in Silicon Valley and Route 128	Book	1994	5.9	87.3	2
49	Dosi G	UK	Sources, procedures and microeconomic effects of innovation	Journal	1988	5.8	31.3	1

50	Freeman C	UK	Networks of Innovators: A Synthesis of Research Issues	Journal	1991	5.8	11.7	1
51	Freeman C; Perez C	UK	Structural crises of adjustment: business cycles and investment behaviour	Chapter	1988	5.8	7.3	1
52	Dodgson M; Bessant JR	UK, Australia	Effective Innovation Policy: A New Approach	Book	1996	5.7	3.1	1
53	Garcia R; Calantone R	USA	A Critical Look at Technological Innovation Typology and Innovativeness Terminology: A Literature Review	Journal	2002	5.7	15.5	4
54	Cowan R; David PA; Foray D	USA, France, the Netherlands	The explicit economics of knowledge codification and tacitness	Journal	2000	5.7	13.6	2
55	Abernathy WJ; Utterback JM	USA	Patterns of industrial innovation	Journal	1978	5.5	17.0	4
56	Vernon R	USA	International investment and international trade in the product cycle	Journal	1966	5.5	32.8	2
57	Chandler AD	USA	Scale and Scope: The Dynamics of Industrial Capitalism	Book	1990	5.2	57.2	2
58	Dosi G; Freeman C; Nelson R; Silverberg G; Soete L	USA, UK, the Netherlands	Technical Change and Economic Theory	Book	1988	5.2	28.1	2
59	Romer PM	USA	Endogenous Technological Change	Journal	1990	5.2	98.0	2
60	Kuhn T	USA	The structure of scientific revolutions	Book	1962	5.0	402.5	3
61	Mansfield E; Schwartz M; Wagner S	USA	Imitation costs and patents: an empirical study	Journal	1981	5.0	9.4	2
62	Mowery DC; Rosenberg N	USA	The Influence of market demand upon innovation: A critical review of some recent empirical studies	Journal	1979	5.0	6.4	1
63	Pasinetti LL	Italy	Structural Change and Economic Growth: A Theoretical Essay on the Dynamics of the Wealth of Nations	Book	1981	5.0	7.6	2
64	Stoneman P	UK	The Economic Analysis of Technological	Book	1983	5.0	8.4	2

			Change					
65	Best M	USA	The new competitive advantage: technology management and regional growth dynamics	Book	2001	4.7	5.7	2
66	Foster RN; Kaplan S	USA	Creative destruction: why companies that are built to last underperform the market, and how to successfully transform them	Book	2001	4.7	9.7	3
67	Granstrand O; Patel P; Pavitt K	UK, Sweden	Multi-technology corporations: Why they have "distributed" rather than "distinctive core" competencies	Journal	1997	4.7	6.1	4
68	Grove AS	USA	Only the paranoid survive: how to exploit the crisis points that challenge every company	Book	1996	4.7	11.6	3
69	Mowery DC; Rosenberg N	USA	Paths of innovation: technological change in 20th century America	Book	1998	4.7	8.5	1
70	Sternberg RJ	USA	Handbook of Creativity	Book	1999	4.7	21.0	3
71	Teece DJ; Pisano G; Shuen A	USA	Dynamic capabilities and strategic management	Journal	1997	4.7	125.3	4
72	Wenger E	USA	Communities of practice: learning, meaning, and identity	Book	1998	4.7	163.1	3
73	Dodgson M	UK	Technological collaboration in industry: strategy, policy, and internationalisation in innovation	Book	1993	4.5	8.9	1
74	Griliches Z	USA	Patent Statistics as Economic Indicators: A Survey	Journal	1990	4.5	32.1	2
75	Jaffe A	USA	Real effects of academic research	Journal	1989	4.5	19.5	2
76	Wheelwright SC; Clark KB	USA	Revolutionizing product development: quantum leaps in speed, efficiency, and quality	Book	1992	4.5	37.6	4
77	Landes DS	USA	The Unbound Prometheus: Technological change and industrial development in Western Europe from 1750 to the	Book	1969	4.4	21.7	2

			present					
78	Fagerberg J	Norway	A Technology Gap Approach to Why Growth Rates Differ	Journal	1987	4.4	3.6	2
79	Griliches Z	USA	R&D, patents and productivity	Book	1984	4.4	13.6	2
80	Mensch G	Germany	Das technologische Patt: Innovationen u□berwinden die Depression (English: Stalemate in technology: innovations overcome the depression)	Book	1975	4.4	10.9	2
81	Nelson RR	USA	The simple economics of basic scientific research	Journal	1959	4.4	7.6	2
82	Rothwell R	UK	The Characteristics of Successful Innovators and Technically Progressive Firms (with some comments on innovation research)	Journal	1977	4.4	4.0	4
83	Rosenberg N	USA	Exploring the black box: technology, economics, and history	Book	1994	4.2	15.3	2
84	Amabile TM	USA	A model of creativity and innovation in organisations	Journal	1988	3.9	12.5	3
85	Mansfield E	USA	Academic research and industrial innovation	Journal	1991	3.9	10.8	1
86	Prahalad CK; Hamel G	USA, UK	The Core Competence of the Corporation	Journal	1990	3.9	100.6	4
87	Robson M; Townsend J; Pavitt K	UK	Sectoral patterns of production and use of innovations in the U.K.: 1945-1983	Journal	1988	3.9	1.9	1
88	Senge PM	USA	The fifth discipline: the art and practice of the learning organisation	Book	1990	3.9	194.2	3
89	Altschuler A; Anderson M; Jones D; Roos D; Womack J	USA, UK	The Future of the automobile: the report of MIT's International Automobile Program	Book	1984	3.9	6.0	2
90	Campbell DT	USA	Blind Variation and Selective Retention in Creative Thought as in Other Knowledge Processes	Journal	1960	3.9	7.0	3
91	Coombs R; Saviotti P; Walsh V	UK	Economics and Technological Change	Book	1987	3.9	3.6	2
92	Dosi G	UK	Technical Change and Industrial Transformation	Book	1984	3.9	7.5	1

93	Drucker PF	USA	Innovation and entrepreneurship: practice and principles	Book	1985	3.9	21.9	3
94	Levin RC; Klevorick AK; Nelson RR; Winter SG	USA	Appropriating the returns from industrial research and development	Journal	1987	3.9	30.6	2
95	Mansfield E	USA	Industrial research and technological innovation: an econometric analysis	Book	1968	3.9	15.7	2
96	Mansfield E; Rapoport J; Schnee J; Wagner S; Hamburger M	USA	Research and innovation in the modern corporation	Book	1971	3.9	7.3	2
97	Penrose ET	UK	The Theory of the Growth of the Firm	Book	1959	3.9	43.8	3
98	Perez C	UK	Microelectronics, Long Waves and the World Structural Change: New Perspectives for Developing Countries	Journal	1985	3.9	4.3	1
99	Polanyi M	UK	The Tacit Dimension	Book	1966	3.9	49.5	3
100	Posner MV	UK	International trade and technical change	Journal	1961	3.9	4.0	2
101	Sahal D	Germany	Patterns of Technological Innovation	Book	1981	3.9	9.8	4
102	Scherer FM	USA	Inter-industry technology flows in the United States	Journal	1982	3.9	3.2	2
103	Solow RM	USA	Technical change and the aggregate production function	Journal	1957	3.9	30.6	2
104	Brown S; Lamming R; Bessant J; Jones P	UK	Strategic Operations Management	Book	2000	3.8	0.6	3
105	Brusoni S; Prencipe A; Pavitt K	UK	Knowledge specialisation, organisational coupling, and the boundaries of the firm: Why do firms know more than they make?	Journal	2001	3.8	11.9	4
106	Chesbrough HW; Teece DJ	USA	When is Virtual Virtuous	Journal	1996	3.8	16.9	4
107	Cooper RG	Canada	From experience: The invisible success factors in product innovation	Journal	1999	3.8	5.9	4
108	De Geus A	UK	The Living Company	Book	1997	3.8	10.5	3

109	Edquist C	Sweden	Systems of innovation: technologies, institutions and organisations	Book	1997	3.8	34.1	1
110	Kanter RM; Kao J; Wiersema F	USA, UK	Innovation: Breakthrough thinking at 3M, DuPont, GE, Pfizer, and Rubbermaid	Book	1997	3.8	1.6	4
111	Landes DS	USA	The Wealth and Poverty of Nations: Why Some are so Rich and Some so Poor	Book	1998	3.8	43.0	2
112	Oliver N; Blakeborough M	UK	Innovation networks: the view from the inside	Chapter	1998	3.8	0.4	1
113	Patel P; Pavitt K	UK	The wide (and increasing) spread of technological competencies in the world's largest firms: a challenge to conventional wisdom	Chapter	1998	3.8	1.5	4
114	Perez C	UK	Technological Revolutions and Financial Capital: the dynamics of bubbles and golden ages	Book	2002	3.8	7.8	1
115	Shapiro C; Varian HR	USA	Information Rules: A strategic guide to the network economy	Book	1998	3.8	75.2	3
116	Trott P	UK	Innovation Management and New Product Development	Book	1998	3.8	2.9	4
117	Weick KE	USA	Sense-making in Organisations	Book	1995	3.8	114.0	3
118	Bryson B	UK	Made in America: an informal history of the English language in the United States	Book	1994	3.4	1.1	3
119	Gibbons M; Limoges C; Schwartzman S; Nowotny H; Trow M; Scott P	USA, UK, Austria, Canada, Brazil	The New Production of Knowledge, the Dynamics of Science and Research in Contemporary Societies	Book	1994	3.4	81.0	3
120	Lundvall B; Johnson B	Denmark, France	The learning economy	Journal	1994	3.4	14.5	2
121	Patel P; Pavitt K	UK	National Innovation Systems: Why They Are Important, And How They Might Be Measured And Compared	Journal	1994	3.4	3.4	1
122	Wolfe RA	Canada	Organisational	Journal	1994	3.4	9.4	3

			innovation: Review, critique and suggested research directions					
123	Argyris C; Schön DA	USA	Organisational learning: A theory of action perspective	Book	1978	3.3	63.1	3
124	Arrow KJ	USA	The economic implications of learning by doing	Journal	1962	3.3	26.4	2
125	Carter CF; Williams BR	UK	Industry and technical progress: factors governing the speed of application of science	Book	1957	3.3	4.1	2
126	Cooper RG	Canada	Winning at New Products	Book	1986	3.3	18.0	4
127	David PA	USA	Clio and the Economics of QWERTY	Journal	1985	3.3	33.5	2
128	Griliches Z	USA	Issues in Assessing the Contribution of Research and Development to Productivity Growth	Journal	1979	3.3	16.4	2
129	Kanter RM	USA	The change masters: Innovations for productivity in the American corporation	Book	1983	3.3	50.3	3
130	Langrish J; Gibbons M; Evans W; Jevons F	UK	Wealth from Knowledge: A Study of Innovation in Industry	Book	1972	3.3	5.9	4
131	Levin RC; Cohen WM; Mowery DC	USA	R&D appropriability, opportunity, and market structure: new evidence on some Schumpeterian hypotheses'	Journal	1985	3.3	4.3	2
132	Mansfield E	USA	Technical Change and the Rate of Imitation	Journal	1961	3.3	10.7	2
133	Mansfield E	USA	How rapidly does new industrial technology leak out?	Journal	1985	3.3	7.3	2
134	Metcalfe JS	UK	Impulse and diffusion in the study of technical change	Journal	1981	3.3	2.0	2
135	Mowery DC	USA	The relationship between intra-firm and contractual forms of industrial research in American manufacturing, 1900–1940	Journal	1983	3.3	3.2	2
136	Nelson RR	USA	A Diffusion model of international productivity differences in manufacturing	Journal	1968	3.3	1.8	2

			industry					
137	Rosenberg N	USA	Science, Invention and Economic Growth	Journal	1974	3.3	2.2	2
138	Salter WEG	Australia	Productivity and Technical Change	Book	1960	3.3	11.5	2
139	Kotler P	USA	Marketing Management: Analysis, Planning, and Control	Book	1967	3.3	56.5	3
140	Barras R	UK	Interactive innovation in financial and business services: the vanguard of the service revolution	Journal	1990	3.2	2.9	1
141	Carlsson B; Stankiewicz R	USA, Sweden	On the Nature, Function, and Composition of Technological Systems	Journal	1991	3.2	7.7	2
142	Fagerberg J	Norway	International competitiveness	Journal	1988	3.2	4.6	2
143	Griliches Z	USA	The search for R&D spillovers	Journal	1992	3.2	18.8	2
144	Hounshell DA; Smith JK	USA	Science and Corporate Strategy: Dupont R&D, 1902-1980	Book	1988	3.2	7.9	3
145	Lamming R	UK	Beyond Partnership: Strategies for Innovation and Lean Supply	Book	1993	3.2	16.9	4
146	Nonaka I	Japan	The knowledge creating company	Journal	1991	3.2	32.9	3
147	Roussel PA; Saad KN; Erickson TJ	USA	Third generation R&D: managing the link to corporate strategy	Book	1991	3.2	13.3	3

*Cluster 1 = Core Innovation Studies, Cluster 2 = Economics and Technology, Cluster 3 = Outsiders, Cluster 4 = Innovation Management.

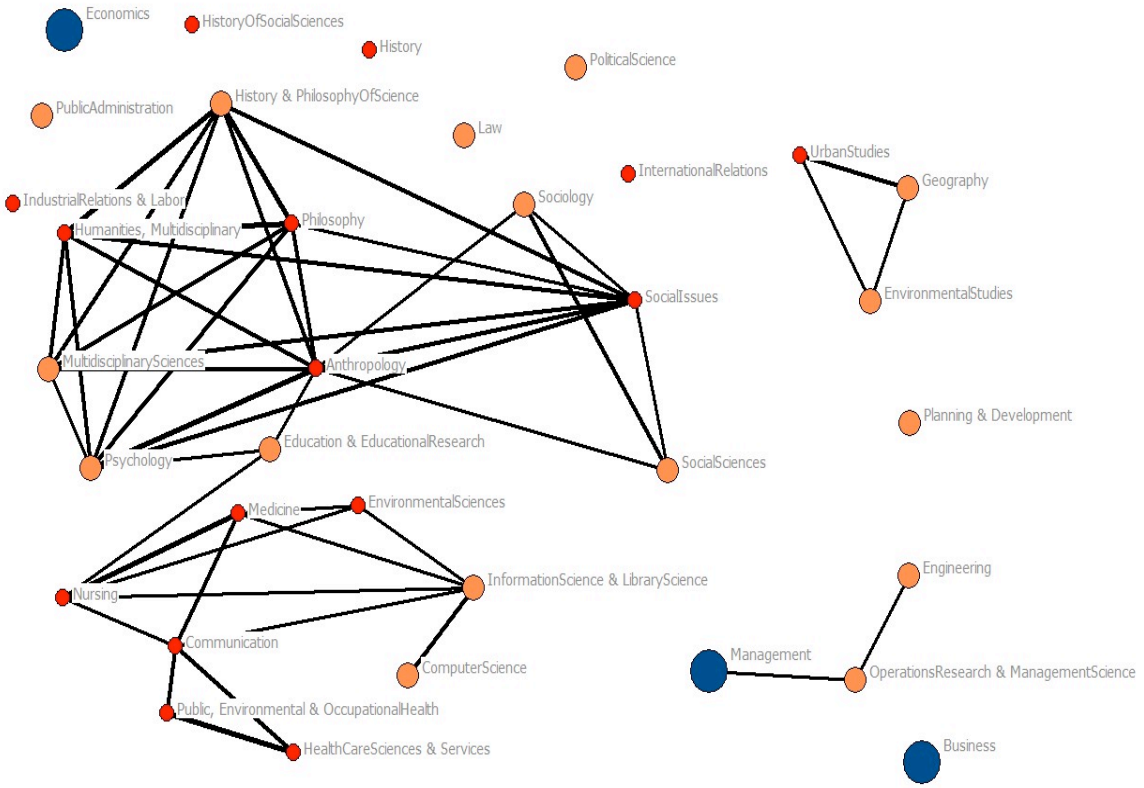
Note: Since the SSCI backfile starts from 1956, ISI/year for the publications prior to this year (Schumpeter 1911, 1939, 1942) was calculated as total ISI citations over the number of years from 1956 to 2008.

Appendix B

Table B. Subject-areas (with number of citations to the core innovation literature > 500) and sub-categories

Subject-areas	No. of citations	Sub-Categories (merged)
Social Sciences and Humanities	26,157	Multidisciplinary Sciences; Psychology (General, Applied, Biological, Clinical, Developmental, Educational, Experimental, Mathematical, Multidisciplinary, Psychoanalysis, Social); Humanities (Multidisciplinary); Anthropology; History & Philosophy of Science; Philosophy; History; Education (General & Educational Research, Scientific Disciplines, Special); Law; Sociology; International Relations; Social Issues; Social Sciences (Biomedical, Interdisciplinary, Mathematical Methods)
Management	22,248	-
Economics	17,094	-
Business	15,796	Business (general, finance)
Engineering	7,830	Engineering (Aerospace, Biomedical, Chemical, Civil, Electrical & Electronic, Environmental, Geological, Industrial, Manufacturing, Marine, Mechanical, Multidisciplinary, Ocean, Petroleum); Operations Research and Management Science
Information and computer science	6,578	Computer Science (Artificial Intelligence, Cybernetics, Hardware & Architecture, Information Systems, Interdisciplinary Applications, Software Engineering, Theory & Methods); Information Science and Library Science
Planning & Development	6,081	-
Geography & environment	5,989	Geography (general, physical); Environmental Studies; Urban Studies
Health	4,637	Environmental Sciences; Healthcare Sciences & Services; Communication; Public, Environmental & Occupational Health; Medicine (General & Internal, Legal, Research & Experimental); Nursing
Political Science	2,200	-
Public Administration	1,348	-
History of Social Sciences	776	-
Industrial Relations & Labour	747	-

Figure B1. Relationships between subject-areas (cut off = 0.9)



Note: This network graph illustrates the relationship between the (main) subject categories, which involves users of knowledge produced by the (core) innovation literature. These relationships refer to the extent to which the sampled publications from two different subject categories cited the same literature (each of the 147 most important works on innovation). Several subject-areas were composed based on these relationships (see Table B). The strength of the relationships is indicated by line thickness, where no lines mean rather weak relationships (less than 90% correlation). The subject categories are represented by circles of different sizes and colours, based on their total amount of citations to the core innovation literature (large blue, medium orange and small red circles).

Appendix C

Table C. Two-Step Cluster Analysis (best solutions based on BIC and log-likelihood distance)

Number of clusters BIC Ratio of Distance Measures	*4* -4264.90 1.24				*3* -4325.30 1.14			*2* -4366.36 2.77	
Cluster (Number of members)	1/4 (28)	2/4 (56)	3/4* (29)	4/4* (34)	1/3* (28)	2/3* (56)	3/3 (63)	1/2 (84)	2/2 (63)
Disciplinary orientation									
Social Sciences & Humanities	0.16	0.19	**0.34**	0.09	0.16	0.19	**0.20**	0.17	**0.20**
Management	0.34	0.18	0.34	**0.50**	0.34	0.18	**0.44**	0.23	**0.44**
Economics	0.22	**0.43**	0.05	0.07	0.22	**0.43**	0.06	**0.36**	0.06
Business	0.20	0.23	0.36	**0.49**	0.20	0.23	**0.42**	0.23	**0.42**
Engineering	0.24	0.14	0.26	**0.48**	0.24	0.14	**0.37**	0.18	**0.37**
Information & Computer Science	0.15	0.09	**0.34**	0.22	0.15	0.09	**0.27**	0.11	**0.27**
Planning & Development	**0.67**	0.41	0.10	0.26	**0.67**	0.41	0.19	**0.49**	0.19
Geography & Environment	**0.25**	0.23	0.05	0.04	**0.25**	0.23	0.04	**0.24**	0.04
Health	0.05	0.04	**0.14**	0.08	0.05	0.04	**0.11**	0.04	**0.11**
Political Science	0.08	**0.12**	0.04	0.02	0.08	**0.12**	0.03	**0.10**	0.03
Generation and selection processes									
RP	**0.54**	0.28	0.04	0.25	**0.54**	0.28	0.16	**0.36**	0.16
SMJ	0.08	0.15	0.17	**0.34**	0.08	0.15	**0.26**	0.13	**0.26**
Insider	**0.36**	0.15	0.06	0.24	**0.36**	0.15	0.16	**0.22**	0.16
Excellence	**0.65**	0.32	0.13	0.38	**0.65**	0.32	0.26	**0.43**	0.26
SPRU	**0.57**	0.01	0.01	0.15	**0.57**	0.01	0.08	**0.20**	0.08
Thematic orientation									
Innovation	0.75	0.07	0.21	**0.76**	**0.75**	0.07	0.51	0.30	**0.51**
Technology	0.36	**0.39**	0.00	0.29	0.36	**0.39**	0.14	**0.39**	0.14
Economy	0.18	**0.34**	0.07	0.00	0.18	**0.34**	0.03	**0.29**	0.03
R&D	0.04	**0.20**	0.10	0.00	0.04	**0.20**	0.05	**0.14**	0.05
Knowledge	0.00	0.02	0.14	**0.26**	0.00	0.02	**0.21**	0.01	**0.21**
Micro	0.00	0.04	**0.52**	0.38	0.00	0.04	**0.44**	0.02	**0.44**
Management	0.00	0.02	**0.14**	0.12	0.00	0.02	**0.13**	0.01	**0.13**
Industry	**0.18**	**0.18**	0.00	0.09	**0.18**	**0.18**	0.05	**0.18**	0.05
Change	0.21	**0.23**	0.00	0.06	0.21	**0.23**	0.03	**0.23**	0.03
Macro	**0.21**	0.18	0.00	0.00	**0.21**	0.18	0.00	**0.19**	0.00

* denotes the two groups of innovation literature which are integrated in the subsequent stage

Note: For Thematic orientation, numbers represent shares of literature within each group which have the respective keyword in the title. Numbers represent variable means for the other two dimensions (Disciplinary orientation, Generation and selection processes). Numbers in bold indicate the highest means/shares.